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BI- DIRECTIONAL GRID-CONNECTED INVERTER FOR MICRO-GRID APPLICATIONS

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ABSTRACT

This paper describes modeling of bi-directional grid-connected inverter for micro-grid applications at steady state and also studies the transient responses for various loading conditions. In this paper mainly the power conditioning unit for micro grid which consists of DC to AC grid connected inverter has been developed. In Inverter simulation model, a 50KW source is connected to the load as well as utility grid. In this simulation model, the power response of load and utility grid is discussed by varying the loads.

KEYWORDS: Micro Grid, Power Conditioning Unit, Bi- Directional Grid Connected Inverter

INTRODUCTION

Now a day's many of the industrial countries generate most of their electricity in large centralized facilities, such as fossil fuel (coal, gas powered) nuclear or hydropower plants because of their power demand. These plants have produce bulk amount of power, which will usually transmit electricity for long distances. But these conventional energy generation systems are not going to last longer and that remaining reserves should be conserved for environmental problems. So to minimize these factors most of the developed countries goes to the on- site power generation by the combinations of renewable energy sources, diesel generators and micro turbines to give the uninterrupted power supply to the load. This type of power generation called Distributed Generations (DGs). It is well known that when many Distributed Generations (DGs) are connected to utility grids, they can cause problems such as voltage rise and protection problem in the utility grid. To solve these problems, new concepts of electric power systems are proposed, and Micro-Grid concept is one of the solutions [1].

A micro grid is a closed small power network consists of dispersed type power sources, which is usually connected to a large grid by tie lines. Ideally it is independently operated as like an isolated network but power interchange is also allowed in order to cancel the difference between supply and demand [3][4][5].

Micro-Grid technologies are playing an increasingly important role in the nation's energy portfolio. They can be used to meet base load, peak power demand, backup power, remote power, power quality, cooling and heating needs.

It can also enable a more efficient use of waste heat in combined heat and power (CHP) applications, which boosts efficiency and lowers emissions. The CHP systems provide electricity, hot water, heat for industrial processes, space heating and cooling, refrigeration, and humidity control to improve indoor air quality and comfort.

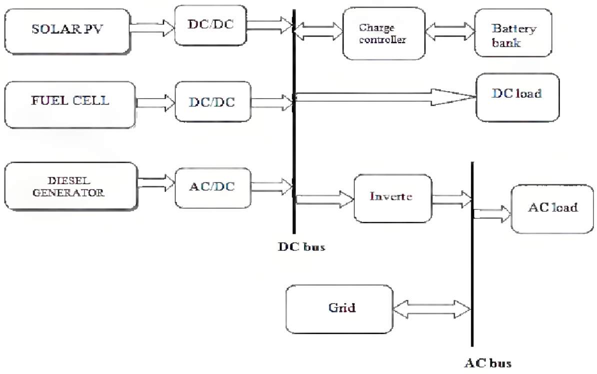

Figure 1: Block Diagram of Micro-Grid

Figure 1 shows the block diagram of the Micro-Grid consisting of solar PV, Fuel cell and Diesel generator. They are connected in parallel to form the constant DC bus by using power electronics converters. The DC bus is connected with the battery bank with the charge controller which controls the charging of the battery bank. The DC loads are connected directly to the DC bus. The inverter is connected to the DC bus which converts DC supply to AC supply and form the AC bus. This AC bus is connected to the AC loads and the utility Grid supply.

Power Conditioning Unit

The power conditioning system provides regulated DC or AC power appropriate for the application. The output of the Micro-Grid sources is an unregulated DC voltage and it needs to be conditioned in order to be of practical use. The power conditioner section converts the raw power into useable power for different applications. The power conditioning unit also controls electricity's frequency and maintains harmonics to an acceptable level. The purpose of conditioners is to adapt the electrical current from Micro-Grid sources to suit the electrical needs of the application. The general configuration of the system will be the Micro-Grid sources followed by a boost converter followed by a Bi-directional grid connected inverter. Here by using the boost converter to maintain the constant DC voltage output from the sources and that DC supply is fed to the inverter system. The boost converter will be operated in the voltage control mode [6], [7].

Based on the load conditions, the boost stage can be commanded to draw a specific amount of current from the Micro-Grid sources with a ripple well defined by the frequency, size of the inductor, and duty ratio. Similarly, the inverter is used for the interfacing of the Micro-Grid system to the load to provide voltage/current with proper frequency phase and magnitude where the input for the inverter comes from the boost converter stage and the inverter (with the filter) becomes the load for the boost converter. An electrical power-generating system that uses Micro-Grid as the primary source of electricity generation and is intended to operate synchronously, and in parallel with the electric utility network is a grid-connected system.

Modeling of Bi-Directional Grid Connected Inverter

Generally, the overall power-conditioning system includes front-end conversion and regulation, for example, DC/DC conversion for renewable energy sources with DC output (e.g., fuel cell, PV), or AC/DC conversion for prime movers with AC output (e.g. micro turbines, sterling engines). They may have an energy-management system, such as a battery charger, at the DC bus. In either case, the input to the inverter is a regulated DC source. In this model, the input to

the inverter is simplified as a DC voltage source. Another simplification is the inverter output filters, which could have different variations in practical applications; for example, the output filter could include L, or LCL, or LC plus a transformer, with or without harmonic filters, etc. To simplify the analysis here, only an L (inductor) filter is considered.

Control Strategy for Grid Connected Inverters

There are two basic control modes for the grid-connected inverters. One is constant current control and the other is constant-power control. It is still arguable whether an inverter should be allowed to regulate voltage during grid-connected operation. The current IEEE standard does not allow Distributed Generation (DG) to actively regulate voltage, but some people in the industry suggest that DG voltage regulation may have some positive impact on the grid.

In this paper constant-current and power-controlled inverters are considered. In detailed analysis, constant-current controlled inverters are used as an example to demonstrate the concepts, which can be easily extended to constant-power controlled inverters. The control design for a three-phase inverter can be realized either in ABC (stationary) or in dq (rotating) frames. Figure 2 shows the inverter with constant current control. The inverter output currents are regulated to the given current references. The controller is greatly simplified with a few key functional blocks like ABC/dq transformation, dq phase-lock loop, summing function, linear regulator (proportional-integral) and dq/ABC transformation. Many functions to deal with practical issues are not modeled, e.g. negative sequence regulation, dq decoupling, device protection, etc.

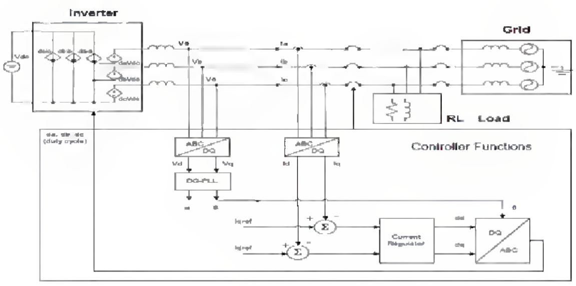

Figure 2: Block Diagram of Constant Current-Control Inverter

Figure 3 shows the inverter with constant power control. There are two key concepts in the dq implementation. First, the active power is proportional to the d-axis components, and the reactive power is proportional to the q-axis components. Therefore, the active and reactive power commands should feed into the d-axis and q-axis, respectively. Second, since the overall vector (voltage or current) is the synthesis of the d and q axes, changing one axis not only changes the magnitude of the vector, but also changes the angle between the d and q axes. The angle change will result in frequency change, because frequency is the derivative of

the angle.

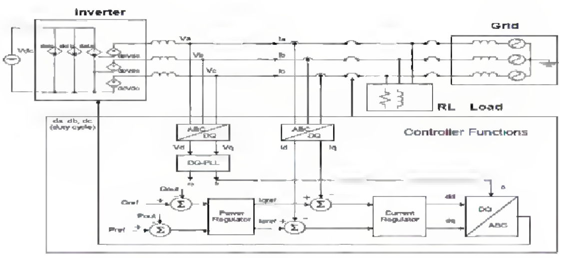

Figure 3: Block Diagram of Constant-Power-Controlled Inverter

Here the inverter output power is compared with the reference power and the error is given to the PI controller, the output of the PI controller represents direct axis current component (d-axis), similarly by comparing the reactive powers, quadrature axis current component (q-axis) component is obtained. These current components is compared with the inverter output currents and the error is given to the PI controllers, the output of the PI controller is current signals which in turn given to the PWM generator and generate the pulses at switching frequency and then fed to the inverter switches.

Simulation Models

Figure 4 shows the SIMULINK model of inverter, current regulator, and power regulator for grid connected applications and its results are presented below

Simulation Model of Power Regulator

Figure 5 shows that the simulation model of the power regulator from this model. In this subsystem the active and reactive powers of the input power, load power and the grid powers are calculated and the reference values of I_d and I_q are calculated.

Simulation Model of Current Regulator

Figure 6 shows the subsystem of current regulator model. In this model the reference values of I_d and I_q are compared with the actual values of I_d and I_q values and the error signal is given to the PI controller. The PI controller will gives the signal to the PWM generator then the PWM generator will generates the gate pulse to the inverter.

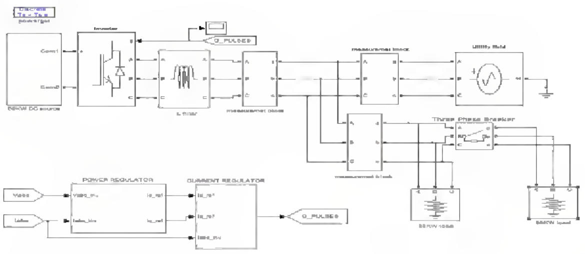

Figure 4: Simulation Model for GRID Connected Applications

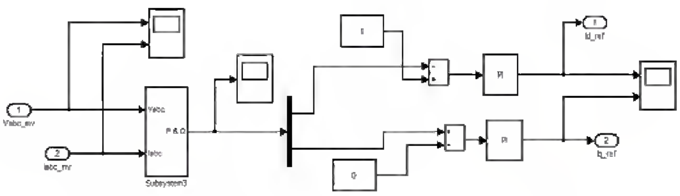

Figure 5: Simulation Model of Power Regulator

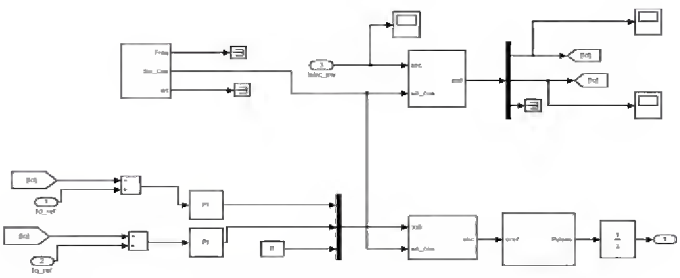

Figure 6: Simulation Model of Current Regulator

Simulation Results

Condition 1: $P_{LOAD} = P_{REF}$

At this condition, power supplied to the grid is zero at steady state. In the transient condition, the grid is giving the power (negative) because due to the slow response of Micro-Grid which is shown in figure 7.

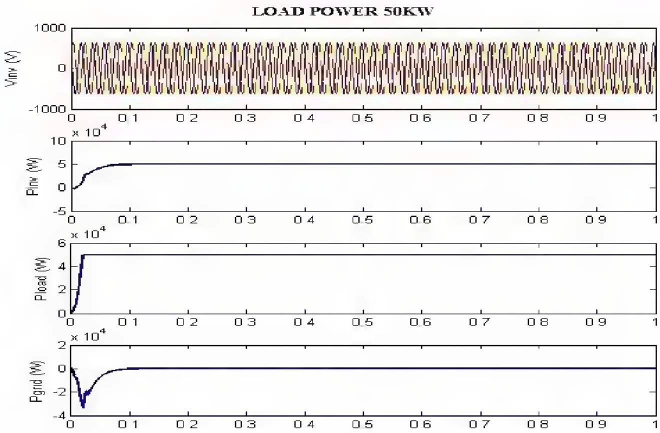

Figure 7: Power Response for 50KW Load

For 50KW of load the current flowing through the load is 92.78 amps (peak) which is coming from the Micro-Grid system (i.e. from inverter) and the current flowing through the grid is zero at steady state. In this simulation for grid connected application, the voltage is maintained constant at a value of 440Vrms line-line (440 √2=622V peak value) for all loading conditions which is shown in figure 8.

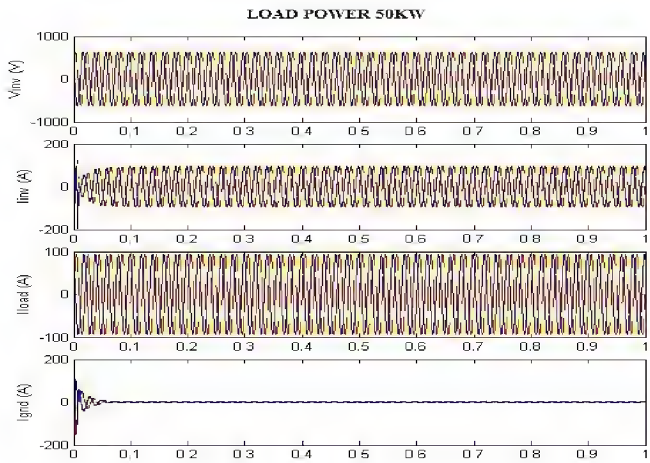

Figure 8: Current Response for 50KW Load

Condition 2: $P_{LOAD} < P_{REF}$

At this condition, power supplied to the grid will be $[P_{REF} - P_{LOAD}]$. If power is taken by the grid, then P_{grid} is considered as positive otherwise negative. The positive value of P_{grid} in the below plot indicates that grid is taking the remaining power from the Micro-Grid system (i.e. from inverter) after supplying to the load. At this loading condition also voltage at the inverter, load is maintained constant which is shown in Figure 9.

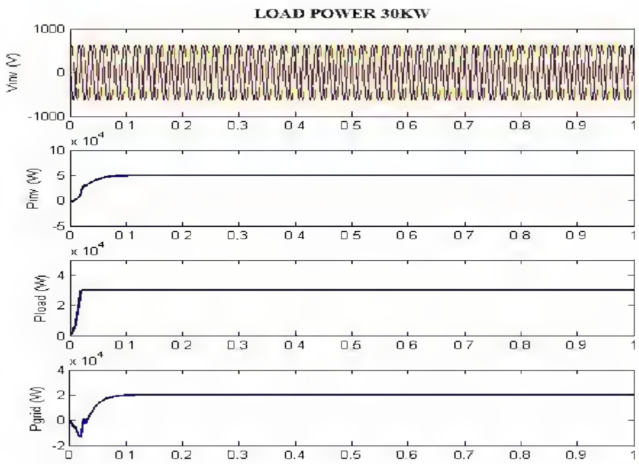

Figure 9: Power Response for 30KW Load

The current flowing from the inverter is 92.78 amps (peak) which is constant for the reference power of 50KW. For 30KW of loading condition, the current flowing through the load is 55.67 amps (peak) which is coming from the Micro-Grid system (i.e. from inverter) and the remaining current 37.11 amps (peak) flowing through the grid which is shown in the figure 10.

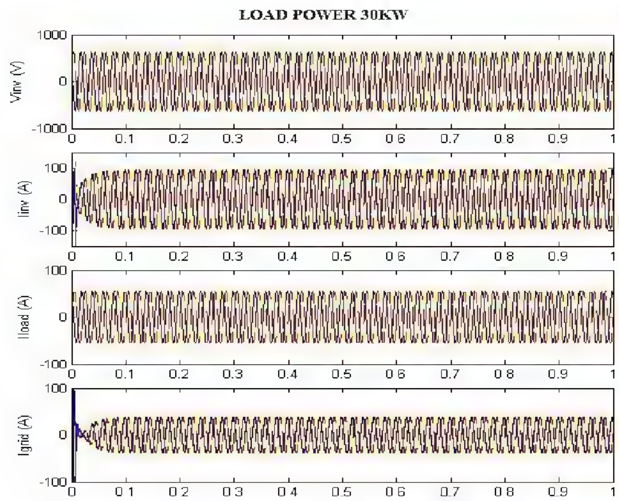

Figure 10: Current Response for 30KW Load

Condition 3: $P_{LOAD} > P_{REF}$

At this condition, power supplied to the grid will be $[P_{REF} - P_{LOAD}]$ which is a negative value i.e. grid (P_{grid}) is supplying the power to the load according to its requirement. For 80KW of load, Micro-Grid system supplying 50KW (reference power) and remaining 30KW is supplied from the grid which is shown in figure 11.

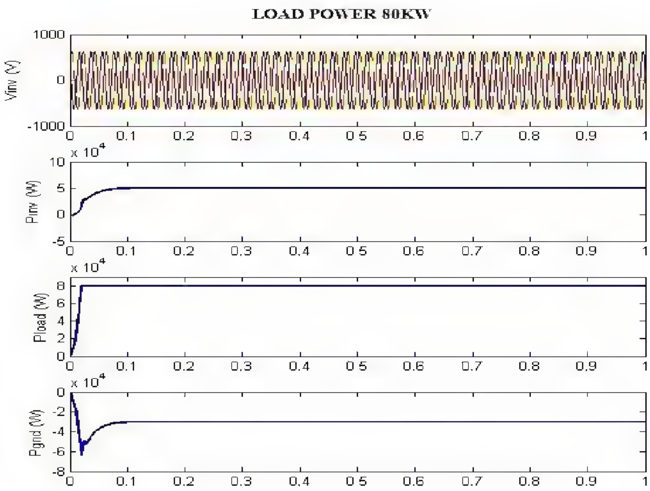

Figure 11: Power Response for 80KW Load

For 80KW of loading condition, the current flowing through the load is 148.46 amps (peak) and the current coming from the Micro-Grid system (i.e. from inverter) is 92.78 amps (peak) which is constant for the reference power of 50KW and the remaining current 55.58 amps (peak) is coming from the grid which is shown in figure 12.

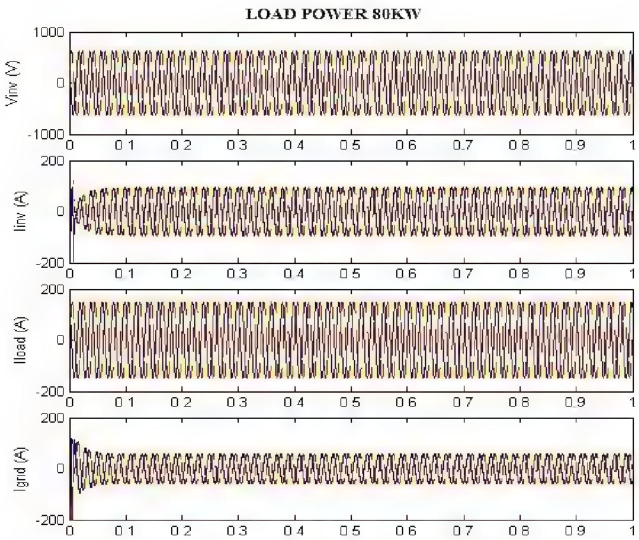

Figure 12: Current Responses for 80KW Load

Condition 4: Step Change in Load form 30KW to 80KW at 0.5 Sec

When there is a sudden change in the load from 30KW to 80KW, both the power taken by the grid and power given to the grid is possible. Up to 0.5 sec the load is 30KW so remaining 20KW of power is given to the grid. After 0.5 sec the load is 80KW, so the grid will supply 30KW of power to the load which is shown in figure 13.

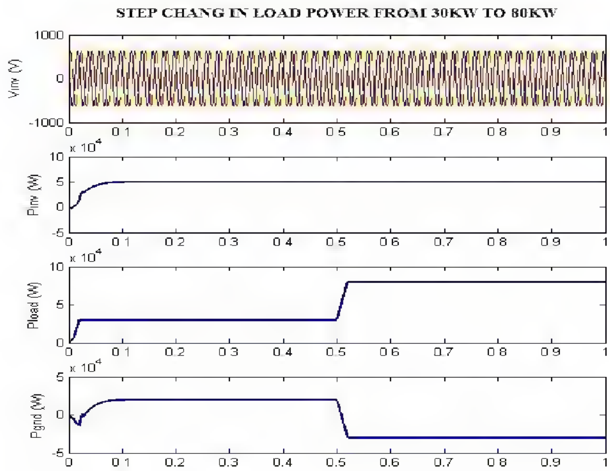

Figure 13: Power Response for Step Change in Load

For step change in load, the current flowing through the load below 0.5sec is 55.67 amps (peak) and the current coming from the Micro-Grid system (i.e. from inverter) is 92.78 amps (peak) which is constant for the reference power of 50kW and the remaining current 37.12 amps (peak) is going to the grid. After 0.5 sec load is 80kW, so the current flowing through the load is 148.46 (peak) amps and the current coming from the Micro-Grid system (i.e. from inverter) is 92.78 amps (peak) and the remaining current 55.67 amps (peak) is coming from the grid which is shown in Figure 14.

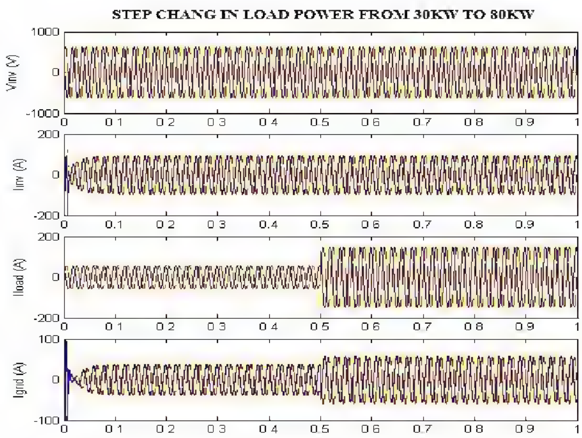

Figure 14: Current Response for Step Change in Load

CONCLUSIONS

In this paper, the Grid-Connected Bi-Directional inverter control scheme using constant power and current control strategies for Micro-Grid system have been discussed. The simulation results for different conditions of loading are analyzed. The real power injection into the grid takes less than 0.1sec to reach the reference value of 50KW. The system was then subjected to a step change in the load from 30KW to 80KW to observe the sharing of power from inverter to grid and from grid to the load, for the 50KW inter connected Micro-Grid source.

REFERENCES

1. M. Bames, G. Ventakaramanan, J. Kondoh, R. Lasseter, H. Asano, N. Hatziargyriou, J. Oyarzabal and T. Green, “Real-World MicroGrids- An Overview,” System of Systems Engineering 2007, IEEE, pp.1-8.

2. N. Jenkins, R. Allan, P. Crossley, D. Kirschen, and G. Strbac. Embedded Generation. The Institution of Electrical Engineers, UK, 2000.

3. R. Billinton, R.Karki : "Capacity Expansion of Small Isolated Power Systems Using PV and Wind Energy", IEEE, Transactions on Power Systems Vol.16, No.4, pp.892-897 (2001)

4. E. D. Dorando, J. C. Pidre, E. M. Garcia : "Planning of Large Rural Low-Voltage Networks Using Evolution Strategies", IEEE, Transactions on Power Systems Vol.18, No.4, pp.1594-1600 (2003)

5. T. Tsuji, T. Oyama, T. Kumano, Y. Kono, I. Iyoda, : "Voltage Control of Demand Area Power System by Autonomous Decentralized Method", IEEJ Trans. PE, Vol.124, No.3, pp. 389-396 (2004)

6. Elshaer, M., Dept. of Electr. Eng., Florida Int. Univ., Miami, FL, USA ; Mohamed, A. ; Mohammed, O., Smart optimal control of DC-DC boost converter in PV systems, Transmission and Distribution Conference and Exposition: Latin America (T&D-LA), 2010 IEEE/PES

7. Hasaneen, B.M. ; Fac. of Eng., Al-Azhar Univ., Kena ; Mohammed, A.A.E., Design and simulation of DC/DC boost converter, Power System Conference, 2008. MEPCON 2008. 12th International Middle-East

8. P. G. Barbosa, L. G. Rolim, E. H. Watanabe, and R. Hanitsch, "Control Strategy for Grid- Connected DC-AC Converters with Load Power Factor Correction," IEEE Proc. Gener. Transm. Distrib, vol. 145, Issue 5, pp. 487-491, September1998.

9. F.Blaabjerg, Z.Chen, and S.B. Kjaer, "Power Electronics as Efficient Interface in Dispersed Power Generation Systems," IEEE Trans. Power Electronics, vol.19, Issue 5, September 2004

10. Z. Ye, R. Walling, L. Garces, R. Zhou, L. Li, and T. Wang, "Study and Development of Anti-Islanding Control for Grid-Connected Inverters" General Electric Global Research Center Niskayuna, New York, NREL/SR-560-36243, May-2004.

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